Teaching methods and their impact on students' emotions in mathematics : an experience-sampling approach

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DOI: https://doi.org/10.1007/s11858-017-0840-1

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Abstract

Various theoretical approaches propose that emotions in the classroom are elicited by appraisal antecedents, with subjective experiences of control playing a crucial role in this context. Perceptions of control, in turn, are expected to be influenced by the classroom social environment, which can include the teaching methods being employed (e.g., direct instruction or small-group work). In the present study we sought to investigate the effect of various types of teaching methods on students' emotions during mathematics lessons with students' control-related appraisals (indicated by pace of instruction and perceived choice) mediating this effect. In a sample of 141 Swiss high-school students, discrete emotions, control-related appraisals, and teaching methods were assessed via the experience-sampling method (i.e., highly ecologically valid real-time assessments) over the course of two weeks (once per mathematics lesson resulting in 807 total lesson ratings). Of the three main teaching method categories, direct instruction was reported most frequently (42.6 %), followed by working individually (24.5 %), and working in small groups or pairs (14.1 %). Results of multilevel analyses revealed that direct instruction was associated with slightly lower levels of positive emotions and higher levels of boredom compared to the other two teaching methods, whereas there were no significant differences regarding levels of anxiety or anger. The impact of teaching methods on emotions was found to be partly mediated by control-related appraisals. The role of teaching methods for fostering students' emotions that are conducive to learning is discussed.

Keywords

Teaching methods, emotions, control–value theory, experience-sampling, direct instruction

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1 Introduction

Emotions have become a focus of educational research in recent years. In addition to cognitive factors, emotions are assumed to have a discernable impact in learning contexts (e.g., with regard to lifelong learning and well-being). As such, fostering positive emotions is regarded as an important aim for teachers striving for student engagement (Buff et al. 2011). Moreover, students' emotions are consistently related to their academic achievement via their cognitive resources, learning strategies, motivation, and self-regulated learning (Goetz and Hall 2013; Pekrun 2006). For these reasons, the study of emotions in the mathematics classroom is of high importance.

Students experience a wide array of discrete emotions, such as enjoyment, pride, anger, anxiety, and boredom, during classroom instruction and learning in mathematics. Students' mathematics-related emotions are assumed to be influenced by the social environment of their mathematics classroom, which includes the various teaching methods they encounter. More specifically, how students *appraise* their mathematics classroom environment is expected to influence their respective academic emotions in that domain (Pekrun 2006).

In heterogeneous classrooms where meeting students' individual needs is often quite challenging, teachers can use a diverse range of teaching methods in order to foster students' learning in many domains including mathematics (Gersten et al. 2009). In addition, teaching methods can and should be utilized to enhance students' motivational and emotional development (Gläser-Zikuda et al. 2005). It is expected that some teaching methods may foster more positive emotions whereas other teaching methods may give rise to increased levels of negative emotions. In the 1980s a shift from teacher-oriented to learner-oriented instruction took place, yet direct instruction still dominates, especially in the domain of mathematics

(Brunner 2014; Givvin et al. 2005; Goetz et al. 2005). As different teaching methods may foster quite different academic emotions in students, it is important to investigate how often different teaching methods are used in mathematics classrooms and how these methods relate to students' discrete emotions. In the present study, students' real-time (i.e., state-level) emotional experiences in mathematics were examined in relation to teaching methods that were assumed to differ according to the extent in which they positively influence students' control-related appraisals. Furthermore, the mediating role of control-related appraisals between teaching methods and emotions was investigated.

2 Theoretical background

2.1 Control-related appraisals as antecedents of academic emotions

As stated above, students' emotions are meaningfully related to their learning, achievement, and well-being. Thus, to promote emotions that are conducive to learning, it is important to understand how emotions emerge in the classroom context. A relatively broad systemic model of teaching is the *'utilization of learning opportunities model'* (*Angebots-Nutzungs-Modell*; e.g., Helmke 2012; Lipowsky 2006). Teachers offer qualitatively different learning opportunities to students, who make differential use of these offers. Thus, how individuals *perceive* their learning environment will influence what learning opportunities they utilize (if any) and, ultimately, how effectively they learn. In the same vein, appraisal theories of emotion contend that it is the individual's interpretation or perception of a personally meaningful situation, rather than the situation itself, that gives rise to his or her discrete emotions (Lazarus 1991; Roseman et al. 1990).

One prominent appraisal theory in the context of academic emotions is the control–value theory of achievement emotions (Pekrun 2006). According to this theory, emotions are assumed to be elicited by appraisal antecedents, namely control and value appraisals. Control refers to a

person's subjective appraisals of whether they can have causal influence over an activity and its outcomes. Value refers to an appraisal of the subjective importance of the content area itself (intrinsic value) or the value of high achievement in the domain (extrinsic value). As proximal antecedents of emotions, control appraisals are assumed to be relevant with regard to *the type* of discrete emotion that should emerge, such as enjoyment, pride, anger, anxiety, or boredom. Control has been found to be positively related to positive emotions and negatively related to negative emotions (Ahmed et al. 2010; Bieg et al. 2013; Goetz et al. 2010; Pekrun et al. 2007; Pekrun et al. 2010). One exception is the emotion of boredom, which is considered to have a slightly negative valence. Unlike other negative emotions, boredom is hypothesized to arise in situations of very high control (i.e., students are under-challenged) *or* very low control (i.e., students are over-challenged, which is expected to be much more common; Pekrun et al. 2010). On the other hand, value is mainly assumed to influence *the intensity* rather than the type of discrete emotion (Pekrun 2000). We focused on control-related appraisals in the present study because we were primarily interested in understanding which academic emotions arise in relation to specific teaching methods rather than the intensity of the emotions.

Subjective control, as understood in the control–value theory, refers to Skinner's (1996) conceptualization of a person's perceived ability to influence actions or outcomes. In the classroom context, different aspects of the social environment may contribute to the feeling of being in control, as also stated in self-determination theory (SDT; Ryan and Deci 2000). For example, being in control, which is framed as feeling autonomous and competent in SDT, helps students to integrate goals into their self-schema, foster self-regulation, and develop intrinsic motivation for engaging with a task. The pace of instruction and the provision of choice are two such examples of control-related appraisals. Students may experience maladaptive emotions when they perceive limited choice provision or when the perceived pace of instruction is not commensurate with their abilities. The important role of control appraisals is also highlighted in several other well-known motivation and emotion theories, including expectancy-value

theory (e.g., Eccles 1983), which emphasizes the role of expectancy or perceived control for persistence and choice in academic contexts, and flow theory (Csikszentmihalyi 1988), wherein an individual is able to reach the state of flow because there is an optimal fit between their subjective control or competence and the task requirements.

2.2 A note on the assessment of academic emotions

An important issue in research on appraisals and emotions is the manner in which they are assessed. When obtaining self-reports of emotions, it is imperative to differentiate clearly between trait (i.e., habitual) emotions, which are assessed as global evaluations of emotions, and state emotions, which are considered to be actual emotional experiences (Robinson and Clore 2002). Trait assessments of emotions have limited ecological validity and have been found to differ from state assessments of emotions (i.e., in situ or real-time assessments of emotions in the actual classroom situation). Specifically, mean-level differences showed that trait emotions are generally rated higher than state emotions (Bieg et al. 2015; Goetz, Bieg et al, 2013). These findings underline the need for state assessments of students' emotions in classroom contexts and support the application of the experience-sampling method (Csikszentmihalyi and Larson 1987; Hektner et al. 2007) to study the impact of teaching methods on emotions.

2.3 Different teaching methods and their influence on control-related appraisal

The control–value theory proposes a host of distal antecedents of students' emotions that can be found in the classroom environment including instruction quality and task demands, value induction, goal structures, achievement feedback and consequences, and autonomy support (Pekrun 2006). The teaching method is another salient environmental antecedent that is expected to influence students' emotions in the classroom via their control-related appraisals.

Moreover, teaching methods have an emotional value per se such as when working in small groups or pairs the social interaction may be a pleasure in and of itself (Deci and Ryan 2002). In the present study, we define a teaching method as a group of specific teaching principles and activities used for classroom instruction. Examples are direct instruction, classroom discussion, small-group work, working in pairs, and individual work (Bohl et al. 2012; Givvin et al. 2005; Hugener et al. 2009). Teaching methods can differ on various dimensions such as how student-centered an approach is or what level of active student participation is required. In educational research, the term *direct instruction* has been used to convey a variety of meanings, and thus it is important to provide an explicit definition (Rosenshine 2008). In the present paper, we understand direct instruction (German "Frontalunterricht") as a method of classroom instruction in which the content, the learning materials, the suggested way of engaging with the material, and the pace are determined by the teacher and are similar for all students in the class. Depending on the individual student's knowledge, achievement level, interest, motivation, etc., this type of instruction can evoke quite different emotions in students.

Previous research has provided insight into the frequency with which different teaching methods are used in mathematics class. Among most of the countries that participated in the Trends in International Mathematics and Science Study (TIMSS; 8th grade students), public interaction (i.e., the teacher or students present to the whole class) was the most frequently used method (Hiebert et al. 2003). In a video-study of German and Swiss mathematics lessons, direct instruction (termed "lecturing") was used most often at the high-school (Gymnasium) level (Hugener et al. 2009). In a study by Goetz and colleagues (2005), teachers from all educational levels were asked how often they used different teaching methods. Among classes in the academic track (i.e., Gymnasium), direct instruction was found to be the most frequently reported teaching method in mathematics followed by individual work, pair work, and working in small groups. As such, across grade levels and countries, direct instruction is the most frequently utilized instructional method among mathematics teachers.

Regarding the relation between teaching methods and educational outcomes, teaching methods have primarily been examined in relation to student achievement (e.g., Seidel and Shavelson 2007), and these studies have yielded inconsistent results (see Hugener et al. 2009; Schukaljow et al. 2012). Schukaljow and colleagues (2012), for example, found that student-centered methods (e.g., small-group work) were associated with higher student achievement when working with mathematical problems, compared to teacher-centered approaches (e.g., direct instruction by the teacher). Conversely, Brunner (2013) found that higher student achievement was associated with teacher-centered methods when students were asked to complete a series of mathematical proofs. However, little research was done on the relation between teaching methods and emotions

We assume that students' control-related appraisals predict the emotions they experience in class and, moreover, that the extent to which the different control-related appraisals are reported by students depends on the teaching method that is being employed. As previously mentioned, one such appraisal that could differ in accordance with the teaching method may be the pace at which teaching proceeds and whether it fits students' individual needs. As direct instruction is typically considered a teacher-centered approach, the pace of instruction is more likely to be too fast (or too slow) as compared to other teaching methods. When working individually or in pairs or small groups students have more control over how fast they proceed with the learning material (Kunter and Baumert 2006). Another control-related appraisal that can be influenced by the teaching method is the provision of choice. If students feel they can choose between different tasks, this may help them to feel more in control of the learning process (Patall et al. 2013; Ryan and Deci 2000). Provision of choice might also be related to the need for autonomy as described in self-determination theory (Rakoczy 2008; Ryan and Deci 2000). Generally, direct instruction is a frequently used teaching method in mathematics as it is considered a feasible way to introduce new and complex concepts to students and to scaffold students through difficult content (Abdu et al. 2015; Bakker et al.. 2015;

D'Ailly 1992a, 1992b; Reusser and Pauli 2015). As direct instruction may limit the perception of choice and the ability to influence the pace of instruction, we assume that this teaching method will have a more negative effect on students' emotions relative to more learner-centered approaches to teaching.

3 The present research

There is a paucity of empirical research on the influence of teaching methods on emotions. To address this research gap, the present study sought to investigate the impact of teaching methods on students' emotions in mathematics class.

Previous research on teaching methods in mathematics education has used one-time self-reports of teachers or students (Goetz et al. 2005; Schwerdt and Wuppermann 2011) or video data (Givvin et al. 2005; Hiebert et al. 2003; Jacobs et al. 2006). Retrospective self-reports of this nature can be problematic as they are prone to bias due to memory distortions or subjective beliefs (Kahneman 2011). Therefore, teacher and student retrospective self-reports of the frequency or type of teaching methods employed may strongly differ from what really happens during actual classroom instruction. To tackle this problem, we used the experience-sampling method to obtain students' reports of teaching methods in mathematics class in situ. These real-time insights into classroom practices should be more ecologically valid as they are assumed to capture what is *actually* happening in the classroom.

We investigated three main research questions:

1) How often are different teaching methods used during mathematics instruction? We assumed that direct instruction would be used most frequently as was found in previous studies.

2) Are different teaching methods accompanied by different levels of enjoyment, pride, anger, anxiety, and boredom? We expected that direct instruction would be related to less positive and more negative emotions for students relative to working individually and working in pairs or small groups. Moreover, we expected boredom to be especially prevalent during direct instruction.
3) Is the relation between the different teaching methods and emotions mediated by control-related appraisals (i.e., pace of instruction and provision of choice) that students report during class? We hypothesized that direct instruction should be related to lower levels of control-related appraisals, which, in turn, would relate to lower levels of positive emotions and higher levels of negative emotions (i.e., control appraisals mediate the relation between teaching methods and emotions).

To answer our research questions, experience-sampling data were analyzed to compare students' control appraisals and emotions during direct instruction, individual work, and pair or small-group work. Based on the extant literature reviewed above, students' control-related appraisals of pace of instruction and provision of choice and their discrete emotions of enjoyment, pride, anger, anxiety, and boredom, were selected.

4 Methodology

4.1 Sample

Data analyzed herein were gathered as part of a larger study that included students from 43 classes in the German-speaking part of Switzerland. As part of a larger program of research, all students initially completed a trait questionnaire that included demographics and additional measures not relevant to the present study. Afterwards, two to four students from each class were randomly chosen to participate in the experience-sampling phase of the study, which included assessments in mathematics as well as in German, English, and French classes. For all

analyses reported in the present paper, only the state assessments in mathematics classes were used. The final sample included 141 9th graders enrolled in 43 classes (54.5 % female, M_{age} = 15.64 years, SD = 0.62). All students were informed about the procedure of the study and gave verbal consent to participate.

4.2 Procedure

Demographic variables were assessed as part of the trait questionnaire. The participants self-reported teaching methods, control-related appraisals, and emotions, which were assessed through a computer-based experience-sampling method (see Hidi 2000). Specifically, our research design combined event-based and random sampling (Shiffman et al. 2008): Participants were provided with an iPod Touch with the iDialog Pad software installed on it (see Kubiak and Krog 2012) and were asked to activate the device at the beginning of every mathematics class (event-based sampling) for a period of two weeks. The device was programmed to randomly signal once within 40 minutes from the start of a lesson (random sampling). Whenever the device signaled, students were asked to answer questions about the current teaching method, the emotions they were experiencing, and their perceived control-related appraisals of the pace of instruction and provision of choice. This procedure resulted in a total of 807 assessment points provided by 141 students, i.e. each student rated 5.72 mathematics lessons on average. There were 104 assessment points that could not be utilized because, at the time of the assessment, a typical teaching method was not being employed (e.g., the teacher was absent due to illness or the students were writing an examination).

4.3 Assessment of teaching methods

Students were asked to indicate the teaching method being employed at the moment their device signaled. The drop down list included direct instruction (German: Frontalunterricht), classroom discussion, presentation (not by the teacher), assignment reviews, individual work, pair work, small-group work, and no class. Working in pairs and working in a small group were considered

to have similar properties (i.e., direct interactions with peers) and were subsequently combined into a single category in the analyses for research questions 2 and 3 (level differences in emotions and mediation via control-related appraisals). In 9.8 % of situations (n = 79), students did not report on the teaching method largely because they missed the signal from the iPod Touch. These missing data points have been excluded from the analyses. Furthermore, all other types of teaching methods that did not fall into the three main categories (i.e., direct instruction, working individually, pair/small-group work) were not considered in the analyses for research questions 2 and 3. Consequently, the number of data points for these analyses was reduced to 591.

4.4 Assessment of control-related appraisals

Two control-related appraisals were assessed during class: pace of instruction [*"At the moment, the teacher is going so fast that I have difficulty following"*] and perceived choice [*"At the moment, I feel that I am provided with choice and options"*] (Goetz, Lüdtke et al. 2013; Kunter and Baumert 2006; Tsai et al. 2008). Each appraisal was assessed with one item on a 5-point Likert scale ranging from (1) *strongly disagree* to (5) *strongly agree*.

4.5 Assessment of state emotions

State emotions were assessed using a single item for each of the five emotions of enjoyment, pride, anger, anxiety, and boredom ["*At the moment, I am experiencing [EMOTION]*"]. Items were adapted from the Academic Emotions Questionnaire (Pekrun et al. 2011). Responses were assessed on a 5-point Likert scale and ranged from (1) *strongly disagree* to (5) *strongly agree*. Single items were used to minimize lesson disruptions and to minimize the likelihood that students reported on their emotional response to the assessment rather than their emotions resulting from the current mathematics class (see Goetz et al. 2010).

4.6 Statistical analyses

To answer our research questions, we first calculated the reported frequencies of all teaching methods over the two weeks of data collection. We then ran regression models that accounted for the two-level data structure with multiple measurement points being nested within students. All analyses were conducted with Mplus 7.11 (Muthén and Muthén 1998-2013). To examine teaching method differences, we dummy-coded the teaching methods variable with direct instruction as the reference category. Thus, the first dummy variable identified individual work, while the second one identified pair/small-group work (e.g., dummy individual work: direct instruction = 0, individual work = 1, pair/small-group work = 0). This procedure allowed us to test for significant level differences in the reported emotions between direct instruction and the two other teaching methods. To answer research question 1, only the descriptive results were needed. To test for different levels of discrete emotions between the different teaching methods (research question 2), regression models including the two dummies as predictors of the different emotions were calculated. To answer research question 3, we ran a regression model with teaching methods as a dummy-coded multicategorical independent variable (see above), pace of instruction and perceived choice as two continuous mediators, and emotions as dependent variables on Level 1 (measurement level) taking into account that multiple measurement points are nested within students (see Hayes and Preacher 2014). Given the mix of dichotomous (dummy variables) and continuous variables, control-related appraisals and emotions were *z*-standardized ($M = 0$, $SD = 1$) in order to obtain standardized results. Specific indirect, direct, and total effects as well as the explained variance (R^2) were calculated for each emotion.[1]

[1] In the absence of a significant total effect of X (independent variable) on Y (dependent variable), there is debate about whether or not it is appropriate to continue with subsequent mediation analyses (Shrout and Bolger 2002). In the present paper there were nonsignificant total effects; yet, we opted to pursue mediation because there may be several instances where nonsignificant total effects manifest, but the assumptions for mediation remain unaffected (e.g., suppression effects; Shrout and Bolger 2002). Therefore, we decided to report the indirect effects although some total effects were not significant (detailed results regarding direct, indirect, and total effects can be found in Table A1 in the Appendix).

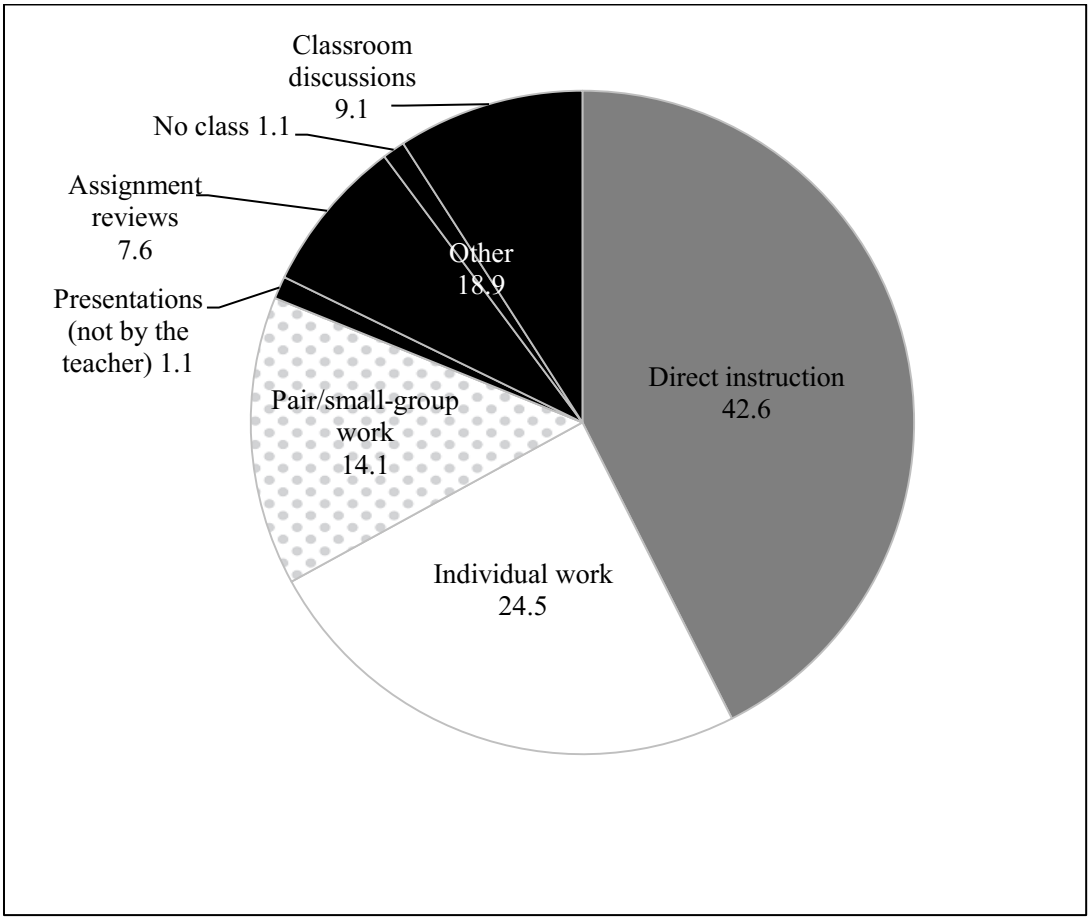
5 Results

5.1 Frequency of teaching methods (research question 1)

Regarding the mathematics lessons for which students indicated a teaching method, the most frequently reported teaching methods were direct instruction (42.6 %) and individual work (24.5 %). Pair work (10.4 %) and small-group work (3.7 %) combined for third most frequent category (14.1 %) followed by classroom discussions (9.1 %) and assignment reviews (7.6 %). The frequencies of presentations (not by the teacher) and no class were relatively low (1.1 % each). For the subsequent analyses, we did not analyze data on classroom discussions, assignment reviews, student presentations, and no class due to their low frequencies relative to the three main categories. The frequencies for direct instruction, individual work, pair/small-group work, and a combined category that includes all other teaching methods are displayed in Figure 1.

Figure 1

Frequencies of teaching methods used in mathematics as reported by students during class time



Note. $N = 728$. Frequencies (in percent) of teaching methods as reported by students during mathematic classes are displayed here. The three main categories of teaching methods are presented and all other methods are combined in the *Other* category.

5.2. Teaching methods and their relation to students' academic emotions (research question 2)

On a descriptive basis, within the three main categories, enjoyment and boredom had the highest mean levels of all emotions assessed; thus, enjoyment ($M = 2.71$, $SD = 1.21$), as a distinctly positive emotion, and boredom ($M = 2.60$, $SD = 1.31$), as a slightly negative emotion, were the most frequently reported emotions in mathematics classes. In Table 1, the descriptive statistics for all emotions and control-related appraisals are depicted for each of the three categories of teaching methods. In Table 2, bivariate correlations between the discrete emotions and control-related appraisals are displayed.

Table 1

Means and standard deviations (SD) for emotions and control-related appraisals for the three most prevalent teaching methods

	Emotions					Control-related appraisals	
	Enjoyment	**Pride**	**Anger**	**Anxiety**	**Boredom**	**Perceived choice**	**Pace of instruction**
Direct instruction (n = 310)	2.58 (1.15)	1.94 (1.16)	2.02 (1.24)	1.49 (1.01)	2.75 (1.28)	1.73 (0.97)	2.63 (1.29)
Individual work (n = 178)	2.81 (1.24)	2.23 (1.36)	2.19 (1.34)	1.40 (0.93)	2.48 (1.31)	2.29 (1.36)	2.18 (1.24)
Pair/small-group work (n =103)	2.92 (1.32)	2.35 (1.32)	1.98 (1.31)	1.56 (1.10)	2.33 (1.35)	2.37 (1.23)	2.28 (1.16)

Note. Emotions and control-related appraisals were rated on a 5-point Likert scale ranging from (1) *"strongly disagree"* to (5) *"strongly agree"*.

Table 2

Bivariate correlation between emotions and control-related appraisals

	Emotions					Control-related appraisals	
	Enjoyment	**Pride**	**Anger**	**Anxiety**	**Boredom**	**Perceived Choice**	**Pace of instruction**
Enjoyment	--						
Pride	.49***	--					
Anger	-.31***	-.12**	--				
Anxiety	-.13**	.03	.43**	--			
Boredom	-.23**	-.08	.27**	.01	--		
Choice	.19**	.20**	.06	.08*	-.15**	--	
Pace	-.24**	-.07	.30**	.32**	.11*	-.03	--

Note. Choice = perceived choice, pace = pace of instruction. * $p < .05$, ** $p < .01$, *** $p < .001$.

Regarding research question 2, hierarchical regression models revealed a slight trend of reporting greater enjoyment when working individually (β = .22, p = .104) and a marginally significant higher enjoyment level when working in pairs or small groups (β = .34, p = .093) compared to direct instruction (M = 2.58). For pride, higher levels were reported while engaging in pair/small-group work (β = .41, p = .008) and individual work (marginally significant; β = .29, p = .055) compared to direct instruction (M = 1.94). No significant differences were found for the negative emotions of anxiety (β = -.08, p = .379 for individual work and β = .08, p = .636 for pair/small-group work) and anger (β = .17, p = .194 for individual work and β = -.04, p = .849 for pair/small-group work). On the other hand, students reported marginally significantly lower levels of boredom while engaging in individual work (β = -.27, p = .053) and marginally significantly lower levels with pair/small-group work (β = -.42, p = .066) relative to direct instruction in mathematics (M = 2.75).

5.3. Students' control-related appraisals and their relation to teaching methods (research question 3)

In the first step, we tested for differences in the control-related appraisals of pace of instruction and provision of choice between the teaching methods. Pace of instruction was rated significantly higher for direct instruction (M = 2.63) compared to working individually (β = -.45, p = .004) but only marginally so for pair/small-group work (β = -.35, p = .073). Furthermore, students reported significantly more perceived choice with individual work (β = .56, p < .001) and pair/small-group work (β = .64, p < .001) compared to direct instruction (M = 1.73).

To test whether control-related appraisals mediated the effect of teaching methods on emotions, we calculated mediation models in M*plus* for each emotion. Significant direct and indirect effects between teaching methods and emotions are depicted in Figure 2.

Perceived choice (β = .17, p = .008) and pace of instruction (β = -.23, p < .001) were found to be significant predictors of enjoyment. Further, no differences were found in levels of enjoyment between different teaching methods when controlling for choice and pace. Both perceived pace of instruction and perceived choice were found to mediate the effect of instruction methods on enjoyment. Specifically, working individually was associated with more enjoyment than direct instruction because the perceived pace was lower and the perceived choice was higher. Further, working in pairs/small groups was associated with more enjoyment than direct instruction because the perceived choice was higher but not because of the perceived pace.

For pride, perceived choice was a significant predictor (β = .18, p =.016) whereas pace of instruction was not (β = -.06, p = .353). Again, no difference was found in levels of pride between different teaching methods when controlling for choice and pace. Perceived choice was found to mediate the effect of instructional method on pride. The indirect effect via perceived choice was marginally significant for working individually and was significant for working in pairs/small-groups.

For anger, pace of instruction was a positive predictor (β =.32, p < .001) whereas perceived choice was not significant (β =.05, p = .383). Furthermore, anger was rated significantly higher when working individually after controlling for pace and perceived choice (significant direct effect between individual work and anger). The indirect effect via pace of instruction was significant for individual work, which meant that there was a lower level of anger due to a slower pace. This indirect effect was marginally significant for working in pairs/small-groups.

Pace of instruction was positively related to anxiety (β = .33, p < .001). Perceived choice was only marginally significantly related to anxiety (β = .09, p = .08). No differences in the level of anxiety were found between the teaching methods when controlling for perceived

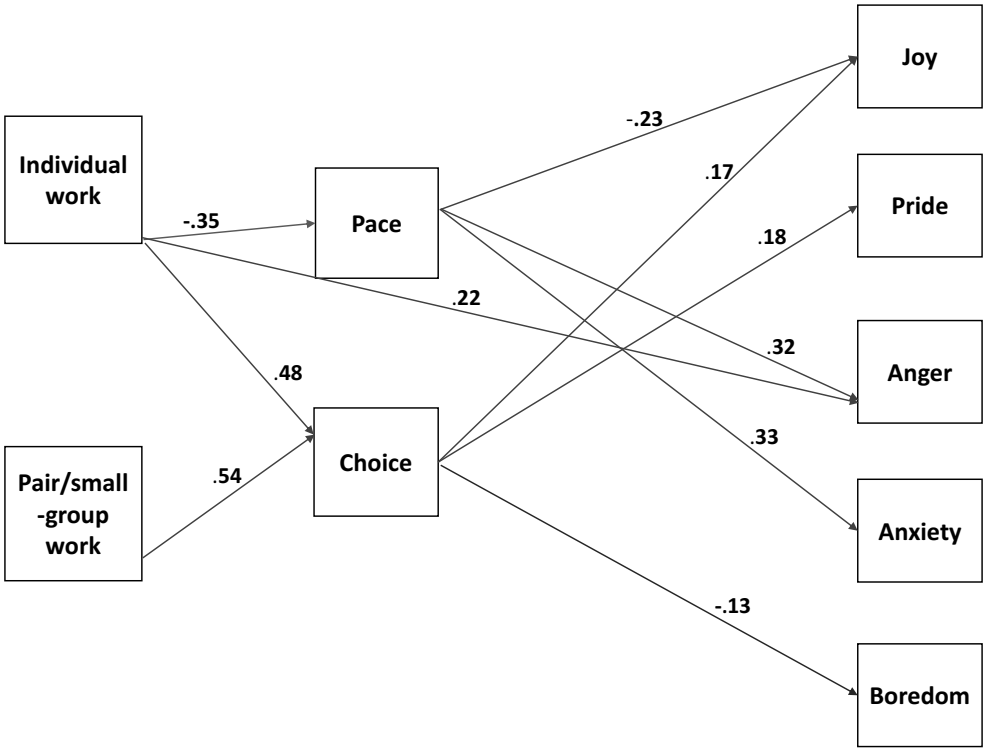
choice and pace. The indirect effect via pace was significant for individual work and marginally significant for pair/small-group work, meaning that a slower pace of instruction in these two teaching methods, relative to direct instruction, was associated with lower levels of anxiety.

Perceived choice was negatively related to boredom (β = -.13, p = .008) whereas pace of instruction was not significant (β = .09, p = .124). No differences were found between teaching methods when controlling for perceived choice and pace. The indirect effects via perceived choice were significant for individual work and pair/small group work, which means that higher perceived choice in individual work and pair/small-group work as compared to direct instruction was associated with lower levels of boredom.

To summarize, perceived choice and pace of instruction seem to be differentially predictive of discrete emotions. Pace of instruction was positively related to the negative emotions of anger and anxiety, meaning that the more students felt the pace of instruction was too fast, the higher their levels of anger and anxiety. Perceived choice was especially important in relation to the two positive emotions of pride and enjoyment. Explained variance was relatively low but significant or marginally significant for all emotions (enjoyment: R^2 = .09, p = .007; pride: R^2 = .05, p = .082; anger: R^2 = .10, p = .082; anxiety: R^2 = .11, p = .007; boredom: R^2 = .04, p = .058).

Figure 2

Depiction of significant effects for individual work (d1) and pair/small-group work (d2) in comparison to direct instruction (reference category)



6 Discussion

The aim of the present study was threefold: (1) to determine frequencies of various teaching methods in 9th grade mathematics classes, (2) to examine relations between teaching methods and discrete academic emotions, namely enjoyment, pride, anger, anxiety, and boredom, and (3) to determine if the control-related appraisals of pace of instruction and perceived choice mediated the relation between teaching methods and emotions. The experience-sampling method was used to assess teaching methods, control-related appraisals, and emotions in situ, which provided real-time data and greater ecological validity relative to retrospective self-reports.

First, when considering the three main categories of teaching methods, traditional direct instruction was reported most frequently, followed by working individually and pair/small-group work, respectively. This finding is in line with past studies that have included students' as well as teachers' self-reports of in-class teaching methods (Goetz et al. 2005; Pauli and Reusser 2010). Thus, although heterogeneity in the classroom appears to be a challenge for many teachers (Kampshoff 2009), our results suggest that direct instruction remains the favored teaching method in the domain of mathematics.

Second, the levels of academic state emotions reported by students varied across the teaching methods. Enjoyment was rated higher on a descriptive basis (i.e., a marked trend or marginally significant effect) when working individually and in pairs or small groups relative to direct instruction. As expected, pride was rated higher for pair/small-group work, but only marginally significantly higher when working individually compared to direct instruction. Students also reported the highest levels of boredom for direct instruction, which differed marginally significantly from pair/small-group work and individual work. Contrary to our expectations, direct instruction was not found to arouse more intense anger or anxiety relative to the other teaching methods. With regard to level differences in emotions, working individually was associated with slightly higher levels of anger. One reason for this finding could be that students' individual achievement is of high importance (high extrinsic value) when they work individually, which may increase their levels of anger as hypothesized in the control–value model (Pekrun 2006).

Third, as compared to the other teaching methods, direct instruction was found to proceed too fast for students. It is important to note that the higher the reported pace of instruction, the more difficult students found it to keep up with the lesson. Additionally, students perceived having more choice when working individually and in pairs or small groups relative to when the teacher was using direct instruction. In an attempt to explain the relations

between teaching methods and academic emotions, we tested for indirect effects via the two control-related appraisals. The results revealed that pace of instruction and perceived choice did explain the relation between teaching methods and some, but not all, emotions. Specifically, perceived choice was a positive predictor of positive emotions and perceived pace of instruction was a positive predictor of negative emotions and negatively related to enjoyment. When controlling for pace of instruction and perceived choice, no significant differences between teaching methods regarding the levels of positive emotions and boredom remained; therefore, a possible way to diminish the negative effects of direct instruction is by taking into account the pace of teaching and the provision of choice for the students.

The high frequency with which direct instruction occurred in the present study indicates that it is an important and heavily relied-upon method of instruction in Grade 9 mathematics; however, relative to other methods, direct instruction has a tendency to be associated with lower levels of positive emotions and higher boredom. To counteract the potential negative effects of direct instruction on students' academic emotions, teachers should consider the potential remedial effects of setting an appropriate pace of instruction and providing students with choice concerning how the learning tasks are conducted. Practically speaking, there may be advantages to informing current and pre-service teachers about these findings (e.g., via professional development seminars and workshops) so that they may create emotionally sound ways of scaffolding their students through difficult content and new concepts while utilizing a direct instruction method. On the other hand, our results suggest that relying more on individual, pair, and small-group work over direct instruction may have positive effects on students' experience of pride in mathematics. As such, inducing greater pride in students may help them feel encouraged by their progress, and optimistic about their ability to solve increasingly challenging problems.

6.1 Limitations and implications for future research

In the present study, we focused exclusively on control-related appraisals as predictors of emotion. Value appraisals were not explicitly tested, nor did we test the role of the interaction between control and value. These are two potential areas for future research as is the examination of moderation effects to understand whether control-related appraisals are differentially related to emotions in the various teaching methods. Such research could shed light on the higher levels of anger that students reported when working individually as compared to other teaching methods. Additionally, given that only 5 to 11 percent of the variance in students' emotions was explained by teaching methods and control-related appraisals, other predictive variables need to be examined including trait emotions, value appraisals, and direct control appraisals ("I am in control at the moment"). This will be an important avenue for future research to link the distal antecedents of the instructional environment to the more proximal cognitive appraisals (see the control-value theory and the utilization of learning opportunities model).

Furthermore, all of our data were purely correlational in nature. Thus, we could not infer causality or rule out the possibility that emotions were influencing control-related appraisals and not the other way around. With regard to mediation analyses, we should also state that strictly speaking we have only tested indirect effects. A longitudinal design is required to verify mediation, which should be considered in future study designs. Additionally, by asking students to report on their emotions in the moment rather than for the specific mathematics-related activity, we may have captured emotions that were relatively unrelated to the teaching method (e.g., enjoyment due to a classmate making a joke).

Another limitation of the present study was that students were not explicitly instructed on how to recognize and evaluate the different teaching methods. As a result, some situations may not have been identified correctly; however, we are confident in the ability of 9th grade

students to differentiate direct instruction from individual work and working in pairs or small groups; however, the distinction between direct instruction and classroom discussion may have been more challenging. Future studies could provide training for participants in advance to help ensure that the respective teaching methods can be clearly distinguished. Perhaps of greater concern is the fact that the item to measure pace assessed only whether the pace was too fast while also containing a difficulty component (*"At the moment, the teacher is going so fast that I have difficulty following"*). Thus, perceived pace may have been partly confounded with perceived difficulty. This is an important limitation that might be addressed in future studies by rewording the item(s) and separating the two aspects. Another possibility might be to use visual analogue scales in future research using appropriate pace as the middle point of the scale.

As the students who participated in the present study were drawn from the highest academic track (around 15-20 % of students in the German-speaking parts of Switzerland; Bundesamt für Statistik Schweiz [Swiss Federal Statistical Office] 2016), our results cannot be generalized to students in other academic tracks. For example, students in lower tracks may be less suited to cope with teaching methods that do not optimally meet their needs, and they may subsequently experience more intense negative emotions. Future research should take into account and compare the different needs of students in relation to different teaching methods so that teachers can be supported in fostering optimal learning environments and adaptive academic emotions. Another limitation of our study concerns the restriction on participants' age as our sample consisted solely of 9th grade students. Examining teaching methods in relation to emotions for different age ranges is needed in order to investigate whether findings generalize to other educational levels.

Two final avenues for future research are worth noting. First, in the present study we were able to analyze intraindividual relations (several measurement points per student, accounting for the nested data structure) which is a clear strength of the present paper; however,

due to too few measurement points per student for the less frequently occurring instructional methods, a larger database was needed to give further insight into the relations between students' control-related appraisals and emotions *specific* to the various instructional methods. Second, it is important to question whether our data reflect *typical* variability in mathematics instruction. In previous research, Pauli and Reusser (2003) did not find any differences between Swiss and German teachers' self-reports of their teaching methods; however questioning whether mathematics teaching methods vary cross-culturally, and whether the relations to students' emotional experiences differ as a result, represents an important direction for future research in mathematics education.

6.2 Conclusion

Direct instruction in the mathematics classroom was the most frequently employed teaching method in the present study. The three teaching methods we examined were associated with different levels of students' emotions, potentially because of students' differing levels of control-related appraisals of each specific form of instruction. Direct instruction, although accompanied by the highest levels of boredom, was not related to significantly higher levels of other negative emotions, including anger and anxiety, relative to other teaching methods. Pair/small-group work was most likely to be associated with students' positive emotions, however, questions still remain, such as: Did students report on their enjoyment for the curriculum or learning activities or were they reporting on other facets of the classroom environment such as social interactions with peers? Especially with regard to direct instruction, teachers are continuously challenged to address students' individual and diverse needs and to foster positive emotions and reduce boredom. Teachers should be aware of the importance of carefully selecting appropriate teaching methods, especially where it concerns direct instruction, to avoid harmful emotion-related side effects and to foster emotions that are conducive to learning.

Acknowledgements

This research was funded by the Swiss National Science Foundation [grant number 100014_131713/1] granted to Thomas Goetz (second author) and Vinzenz Morger (sixth author).

This is a post-peer-review, pre-copyedit version of an article published in ZDM Mathematics Education. The final authenticated version is available online at: http://dx.doi.org/10.1007/s11858-017-0840-1

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Appendix

Table A1

Total, indirect, and direct effects of the multicategorical mediation analysis

	Enjoyment	Pride	Anger	Anxiety	Boredom
Individual work					
Total EMO on D1	.19	.23†	.13	-.08	-.20†
Total Indirect EMO on D1	.16**	.11	-.09	-.08	-.10*
Indirect EMO on D1 via Pace	.08*	.02	-.11**	-.12**	-.03
Indirect EMO on D1 via Choice	.08*	.09†	.02	.04	-.06*
Direct EMO on D1	.02	.13	.22*	-.01	-.11
EMO on Pace	-.23***	-.06	.32***	.33***	.09
EMO on Choice	.17**	.18*	.05	.09†	-.13**
Pace on D1	-0.35**	-0.35**	-0.35**	-0.35**	-0.35**
Choice on D1	0.48***	0.48***	0.48***	0.48***	0.48***
Pair/small-group work					
Total EMO on D2	.28	.33**	-.03	.08	-.32†
Total Indirect EMO on D2	.16**	.11*	-.06	-.04	-.10*
Indirect EMO on D2 via Pace	.06	.02	-.09†	-.09†	-.03
Indirect EMO on D2 via Choice	.09*	.10*	.03	.05	-.07*
Direct EMO on D2	.12	.22	.03	.12	-.22
EMO on Pace	-.23***	-.06	.32***	.33***	.09
EMO on Choice	.17**	.18*	.05	.09†	-.13**
Pace on D2	-0.27†	-0.27†	-0.27†	-0.27†	-0.27†
Choice on D2	0.54***	0.54***	0.54***	0.54***	0.54***

Note. EMO = emotion; D1 = individual work; D2 = Pair/small-group work

† < .10, * p < .05, ** p < .01, *** p < .001.